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CORROSION WEAR IN MODERN ENGINES

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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

CORROSION WEAR IN MODERN ENGINES

by

G. B. Rutenburg

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13. ABSTRACT

In this examination of the causes and measurements of engine wear, the author asserts that the possibilities of increasing operation intervals between repairs of Soviet engines through improved fuel and oil anticorrosion characteristics and by the use of automatic devices for controlling fuel have not been developed as much as they should. This is indicated by the fact that under the present GOST standard 2089-64, gasoline content of sulphur is higher wheras it is insignificant under American standards. With regard to abrasion wear of engines because of dust, this factor is seasonal in most sections of the Soviet Union. The results are given of tests described in an article published earlier in the same journal named above (Gureyev, A. A., et al, 1966, no. 12) investigating the wear resulting from starting carburetor engines. In these tests, comparisons were made in the cooling chamber of three such engines of the ZIL-375 type, one of which started after initial warmup by a type P-100 heater while the other two were not warmed up. Results of the tests showed that the wear in the cylinders measured by a micrometer was 19 mu after 100 starts with warmup, and 19-26 mu after that many starts with no warmup. However, the resultant conclusion by the authors of that article that the wear due to starting is insignificant is disputed by the author of the present one, and he proceeds to prove his ideas. [AF2000388]

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Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* <u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

CORROSION WEAR IN MODERN ENGINES

G. B. Rutenburg

In recent years the automotive industry has achieved a significant prolongation of engine life providing operation without major overhaul up to 200,000 kilometers of travel. A factor limiting the period of engine operation prior to major overhaul continues to be the wear of parts of the piston-cylinder group.

Many studies have been devoted to the question of wear of these parts, as a result of which the essential role of not only abrasive but also corrosion wear has been established [1-5].

In accordance with these studies in world practice there has been an increase in motor vehicle engine life not only as a result of improvement of means for protecting the engine against dust, but also by using improved grades of oil and fuel and using devices to ensure rapid heating of the engine and

maintenance of optimum heat conditions.

On Russian engines,the actual capabilities for increasing road time between overhauls by means of improving the anti-corrosion qualities of the fuel and oil and also by the use of automatic devices for regulating the heat conditions have been far from realized. As witness to this is the fact that the current All-Union State Standard [GOST] 2089-64 still permits production of motor vehicle gasoline with a somewhat increased content of sulphur, whereas according to American standards the permitted sulphur content is insignificant. Articles published in recent yearson the question of ways of further increasing the life of engines have called attention to under-rating the role of corrosion wear.

In these articles, despite the total picture compiled in the entire world, an attempt was made to prove the insignificance of corrosion wear of engine parts, in particular, the considerable effect on them of cold starts was disputed. In [3-5] the decisive role of abrasion wear under the effects of dust is emphasized. However, in most regions of the USSR this factor has a seasonal character. Engine wear due to dust is considerably reduced through improvement of filters and by the expansion of the network of asphalt-covered roads.

Since abrasive wear is taken as the main mechanism of wear, the role of a seasonal factor is overestimated and the constantly

acting factors of wear are overlooked: the quality of the fuel and oil, the heat conditions of engine operation.

There the question of the causes of wear has serious practical value. This is why it is important to determine how trustworthy the experimental data are which are based on conclusions as to the unimportance of corrosion wear for modern engines.

The majority of the articles recalled were founded on individual tests which were made for the purpose of proving the harmlessness of cold engine starts and directed to substantiating the value of the expediency of wide use of such starting devices as the "Start Pilot" on Russian automobiles.

Considering that actually a series of these tests were used as one of the main bases for denying the considerable role of corrosion wear, it is necessary to consider in detail as a primary source the article in the magazine " Automobile Industry" devoted to a study of starting wear of carburetor engines [4]. The article is based on the results of comparative tests in a cold chamber of three carburetor engines of the ZIL-375 type, of which one was started after preliminary heating by a P-100 preheater and the other two without warming-up, i.e., in cold state.

All three engines were cooled to -25° and after each start were warmed up for 15 min at idling speed. In all, 100 cycles

were run for each machine, consisting of a start, warm-up, and cooling. The tests were conducted with the same ASZp-10 oil and A-76 gasoline.

Results of measurement of the cylinder liners made before and after the tests showed that the average maximum diameter wear I of the cylinders measured with a micrometer amounted to 19 μm after 100 starts with warm-up and 19-26 μm after starts in cold state.

With measurements made by the micro-indentation method the values of wear were 8 and 12 μm respectively.

On the basis of these data, the conclusion was made in the article that engine wear both in preheated engines and cold engines after 100 starts proved to be insignificant in absolute values.

This conclusion disagrees with the hitherto generally accepted concepts regarding the decisive role of starting wear and is in contradiction with factory instructions regarding the inadmissibility of cold starting of engines. Such a new statement of the question, naturally, must be thoroughly substantiated and be based on reliable experimental data.

However, if one turns to the material presented in the article it is not difficult to establish not only the significant

methodical inaccuracies in the tests conducted, but principally, proceeding from the factual data published in the article, it is easy to demonstrate the error of the conclusions made in regard to the insignificance of starting wear.

Let us dwell on the method of conducting the tests since a consideration of certain incorrect statements in it will permit clarifying why, in distinction to the many previous studies by the authors, it was not possible to observe a significant difference between starting wear in a cold and in a preheated engine.

The high starting wear of cylinder parts of the piston group has been explained up to now by corrosion effects. The intensity of this wear with other conditions being equal was determined solely by the thermal state of the engine, i.e., by the temperature of the walls of the combustion chamber and the cylinders at the beginning of starting and at the conclusion of heating. In so doing, the greatest intensity of wear, as has now been established by many studies [1 and 3], occurs not at the first brief moment of the start itself but in the subsequent incomparably more prolonged period of its warmup, in the course of which the temperature of the coolant and the oil comparatively slowly reaches maximum values. This significant effect of temperature of the engine on the intensity of corrosion wear is confirmed by all studies, without exception, made both in our country and abroad (Figs. 1 and 2).

In studying the causes of wear of automobile engines, the American experts pay great attention to wear on starting essentially of a warm engine (from 20° and higher), since precisely in these temperature conditions the engine in its period of service in the automobile is started tens of thousands of times and therefore total starting wear has important significance for its life. As Fig. 1 shows, even under favorable conditions when the engine is started in a warm state, the intensity of ring wear depends on temperature.

Therefore, in estimating starting wear of engines it is important to take into account their thermal state, and only by preserving identity in respect to the given parameter can it be considered that in respect to corrosion wear the engines will be put in comparable conditions.

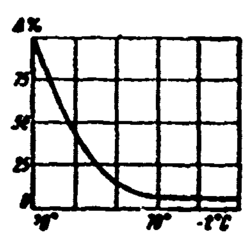

Fig. 1. Starting wear of piston rings depending on temperature t(Δ - relative ring wear).

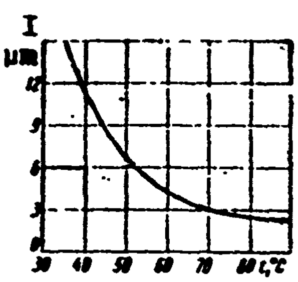

Fig. 2. Average maximum wear I of cylinders of a YaMZ-236 engine after 75 starts(t_1 - average temperature of cylinder walls during starting and warmup).

However, this decisive requirement was not fulfilled in the studies in question and the engines being compared at the end of a 15-minute period of idling had non-uniform temperature of the cylinder walls. In this case, with a preheated engine which before starting already had an antifreeze temperature of 80-90^{o} and an oil temperature of 60^{o}, after 15 minutes of warming up at idling revolutions the temperature of the cylinder walls was about 110^{o}.

At the same time, for a cold engine which before starting was not preheated and had an initial antifreeze temperature not of 80^{o} as in the first case, but -25^{o}, after the same 15 minutes of running idle the temperature of the cylinder walls did not exceed 60^{o}.

Consequently, by not bringing the cold engine after starting to a thermal state identical with the state of the fully warmed engine, the authors artificially almost doubled the period of intensive wear and obtained for it a correspondingly reduced value of starting wear.

Another very significant error permitted during the study consists of the following. The cold starts of the engine are inevitably accompanied by considerable accumulation of condensate of water and fuel in the engine crankcase, which leads to a sharp reduction in the quality of the oil, thereby causing increased wear not only as a result of corrosion effects during

starting but also by reason of direct rusting of engine parts during prolonged standing of the automobile.

It is sufficient to point out that according to studies, a 2-3% content of water in the oil increases wear of cylinders and rings several times [1]. An accumulation of a large quantity of water in the crankcase oil during starting and warm-up of a cold engine occurs as a result of condensation of water vapors which form during the heating of hydrogen contained in the fuel.

The fact of a significant accumulation of water and gasoline in the engine crankcase is also confirmed in the article in question. However, the authors of the study figured that it is possible to eliminate the effect on wear of this very significant factor by changing the oil in the cold engine after every 10 starts.

The admissibility of such frequent changing of the oil is based on the presence of increased air moisture in the cooling chamber and also on the circumstance that under actual conditions of operation the dilution of the oil does not reach great values since, after starting, the engine is loaded and the oil temperature increases so much that the basic part of the gasoline fraction, boiling at low temperature, evaporates from the oil.

In the article, experimental data are provided demonstrating

this well-known truth, the correctness of which in relation to fractions of gasoline boiling at low temperature cannot be doubted. However, in the article there is no evidence whatsoever of the rapid evaporation of water accumulated in the engine oil during cold starts. In fact, under actual operating conditions, especially in winter when the engine runs constantly with supercooling, the temperature of the oil is considerably below 100° and therefore the removal of water from it proceeds extremely slowly. Furthermore, the article does not provide a sufficient basis for the frequent change of oil in referring to the high air moisture in the cooling chamber. In fact, the amount of moisture sucked into the engine together with the air, even with 100% moisture content, comprises an incomparably smaller value in comparison with the quantity of water formed as a result of the combustion of gasoline.

With each oil change for the cold engine in the case under discussion, not only water was removed but also the products of oxidation of the oil and "abrasive iron" which in actuality, by remaining in the oil, play a rather large role in wear.

Therefore, there is every basis to confirm that by means of frequent oil changes, the authors of the study alleviated the conditions for cylinder wear during starts of the cold engine, obtaining for it reduced values of wear. In confirmation of this we can cite the results of similar tests carried out at the Automobile and Automobile Engine Scientific Research

Institute [NAMI] on YaMZ-236 automobile engines. During these tests, the oil during starts of the cold engine was changed after every 40 starts, i.e., considerably less frequently, and in this case, as shown in Fig. 3, the cylinder wear in starting the cold engine proved to be significantly higher than in the case of starting a preheated engine.

The mentioned essential shortcomings in the method of conducting the tests doubtless lower the scientific value of the published materials. Nevertheless, the factual data included in the article, which were obtained as shown above, by an imperfect method, are fully sufficient to refute the main conclusion of the article, confirming that the wear of engine parts after 100 starts is insignificant in respect to absolute values.

The absolute numerical values of cylinder wear still do not provide a basis for estimating their values, since these figures must be compared with actual wear obtained in tests of an engine in an automobile and on a test stand.

For a tentative representation regarding the significance of the obtained values of starting wear we use as an example the results of forced road tests of ZIL-130 engines with a minimum number of starts. The results of a comparison of wear are provided in Fig. 4 From it, it is not difficult to establish that the insignificant, according to the authors, average maximum value of wear of sleeves (10-19 μm) obtained after 100 starts

exceeds the wear of a similar engine after running the automobile 150,000 km.

Consequently, if we proceed on the basis of the published data, it turns out that one start and warm-up of a carburetor engine is equivalent in wear to more than 1500 km of running the automobile during forced road tests.

A similar presentation regarding the great significance of starting wear provided in the article can also be obtained by comparing it with the wear during bench tests of engines in accordance with GOST 491-55. Results of bench tests of ZIL-130 engines showed that sleeve wear produced after 100 starts corresponds to engine wear after 600 hours of running on the bench, i.e., one start is the equivalent of 6 hours of intensive running of the engine.

The untenability of the conclusion regarding the insignificance of starting wear can be very graphically shown by the following simple example. If one considers that according to statistical data for 1000 km of running that the automobile engine must be started no less than 30 times, then in running the automobile 150,000 km prior to major overhaul, no less than 4500 starts will be made on it. We assume that all starts will be made under the most favorable conditions, i.e., when the engine is thoroughly warmed up before starting in each case. Then, proceeding on the basis of even the most minimal value

of starting wear presented in the article in question (8 μm per 100 starts) we find that total wear of cylinder sleeves when the engine is put in for major overhaul due only to starting comprises 360 μm.

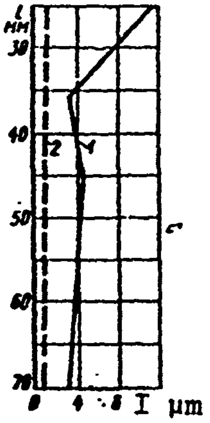

Fig.3 Average cylinder wear of a YaMZ-236 engine after 75 starts and warm-ups (l - distance from upper surface of the block):

1 - temperature of cylinder before start -25° (oil ASZp-10); 2 - temperature of cylinder before start +74° (oil DSp-8).

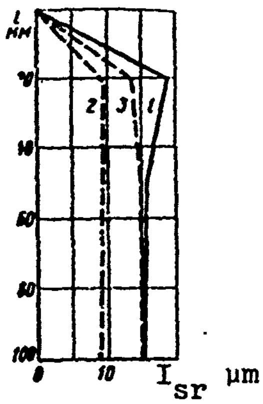

Fig.4 Comparative estimate of starting wear of ZIL-130 engine (I_{sr} - average wear of cylinder sleeve):

1 - wear after 100 starts and warm-ups; 2 - wear after 150,000 km of forced road test; 3 - wear after 600 h bench test of engine.

If one compares the obtained value (360 μm) with the actual standards for sleeve wear before replacement (400 μm), then it becomes clear that the necessity for major overhaul of the engine will be determined in this case almost exclusively by starting wear.

Up until now, by attaching serious importance to starting wear, they proceeded from the fact that it comprised half of the operational wear. The factual data published in the article in

question not only do not refute this, but, on the contrary, point to a still greater role for starting wear in modern engines.

The examples considered give no basis whatsoever for disregarding corrosion wear of engine cylinders and show that during operation in respect to further increasing the service life of our own engines it is necessary to pay serious attention not only to protecting the engine from dust, but it is extremely necessary to take measures directed to reducing corrosion wear:

1. To ensure that automobile fuel has a minimum sulphur content.

2. To organize the production of engine oils with anti-corrosion and anti-wear additives corresponding to the requirements of world standards.

3. To eliminate the causes for removing engine thermostats by increasing the reliability of their operation, and also by wide use of antifreeze and devices for pre-start warming up of the engine.

EDITOR'S NOTE

Publication of this article by G.B.Rutenburg concludes the discussion begun in 1966 of articles by Comrades M.A.Grigor'yev, N.I.Ponomarev, and Ye.I. Shanin on the subject: "Cylinder Wear in Automobile Engines." As a result of the discussions it became evident that notwithstanding the sharp increase in the life of new automobile engines, the ratio between individual wear components of parts of the cylinder-piston group has changed

insignificantly. Along with abrasive wear of cylinders and piston rings, a very great role is played by starting wear and corrosion wear.

Under these conditions it is necessary, along with improving the protection of the engine from abrasive particles getting in through the air,oil,or fuel, to improve the anti-corrosion properties and life of auto engine oils, to ensure a stable optimum thermal condition for the engine, and to use more long-lasting materials in the main wearing parts and components of the engine.

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